High current coated conductors based on IBAD YSZ and thick YBCO / Sm-123 multilayers

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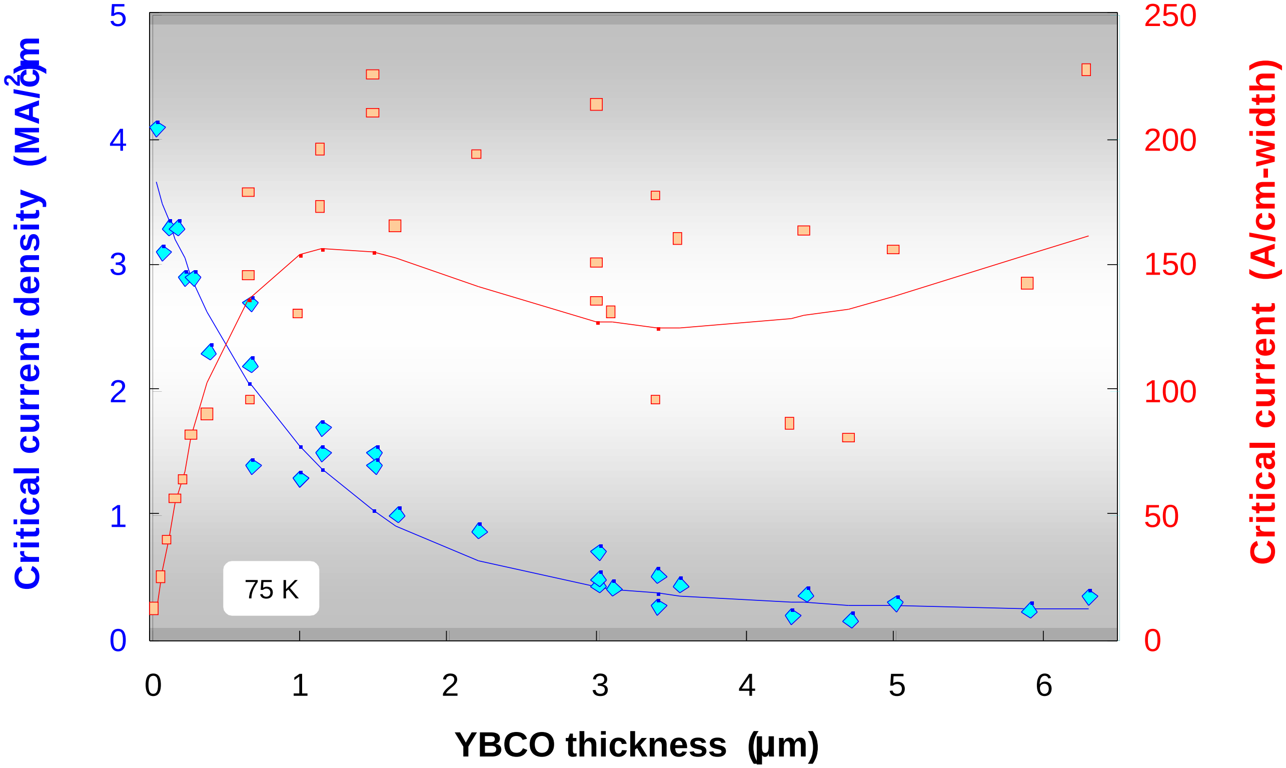
Research on thick YBCO is important for several reasons

- Retain high current in a magnetic field at liquid nitrogen temperature
  - 100 A/cm-width at 1 T (B||c) requires >500 A/cm in self field
- Achieve high J_e at liquid nitrogen temperature
  - 100,000 A/cm^2 requires I_c >500 A/cm on 50 μm thick substrates
- Explore the limits of coated conductor technology

Previously we showed that a tape current "limit" of ~200 A/cm-width was reached at a YBCO thickness of ~1.5 microns

PLD YBCO on Inconel substrates with Y_2O_3- or CeO_2-buffered IBAD YSZ

Bridge dimensions: ~200 μm x 5 mm



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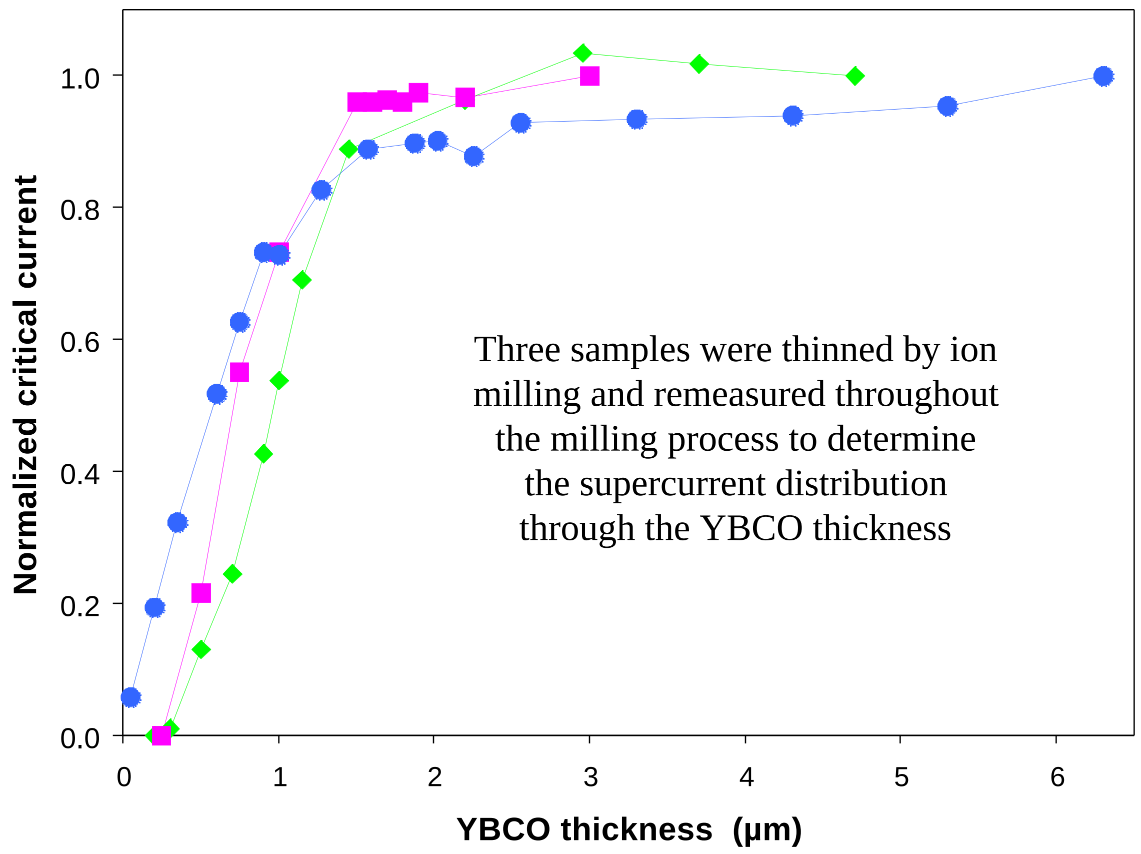
Ion milling experiments revealed that little or no current was carried in the top layers



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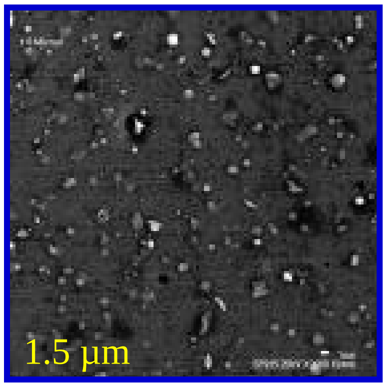
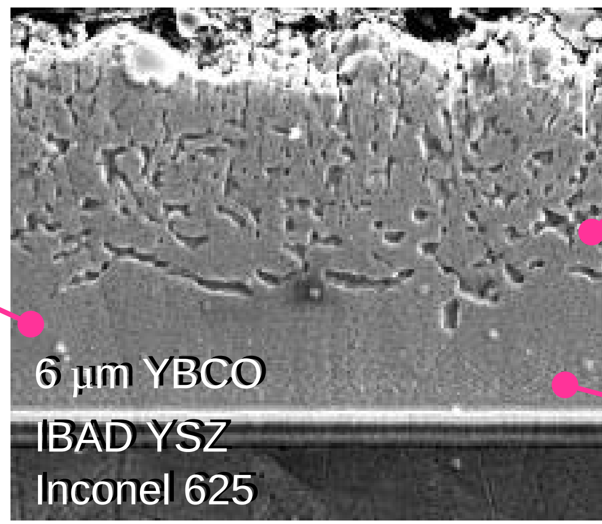
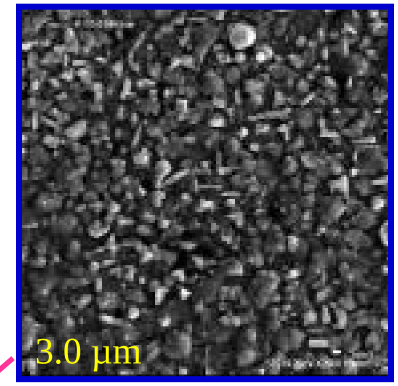
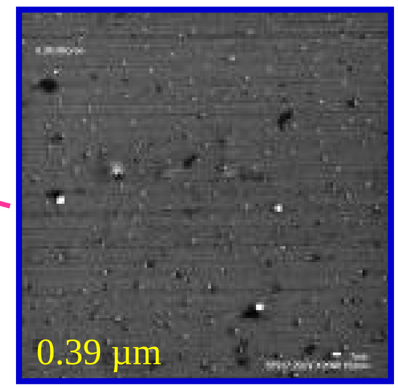
The problem at levels above 1.5 μm appears to be related to roughness-induced porosity as the YBCO becomes thicker

SEM plan views (2000x) show increased roughening with thickness, which leads to the poor connectivity shown in SEM cross-section

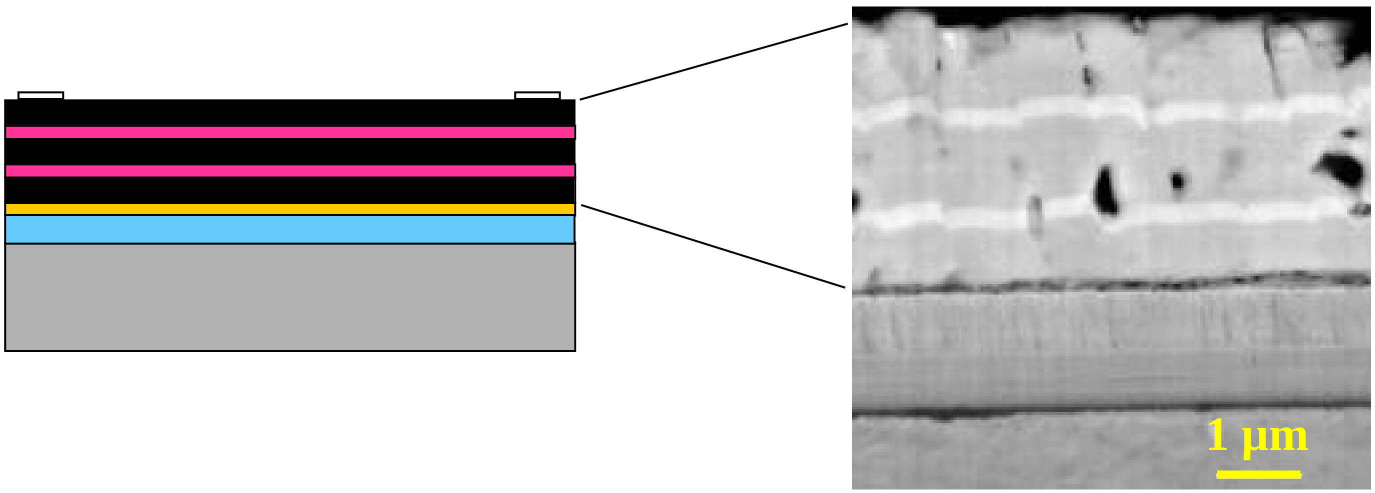








In an attempt to "reset" the YBCO morphology, we used interlayers of Sm-123, which by itself yields very smooth coatings with low J_c



Silver contact
YBCO
$Sm_1Ba_2Cu_3O_{7-\delta}$
CeO_2
IBAD YSZ
Inconel

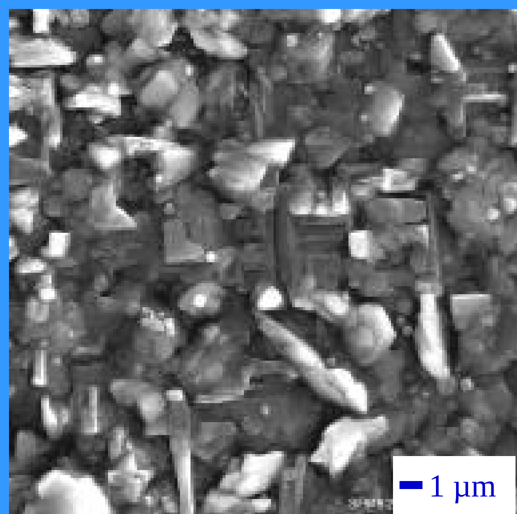
<u>Y - Sm - Y - Sm - Y multilayer</u>

YBCO thickness: ~1.0 µm

SBCO thickness: ~ 0.2 µm

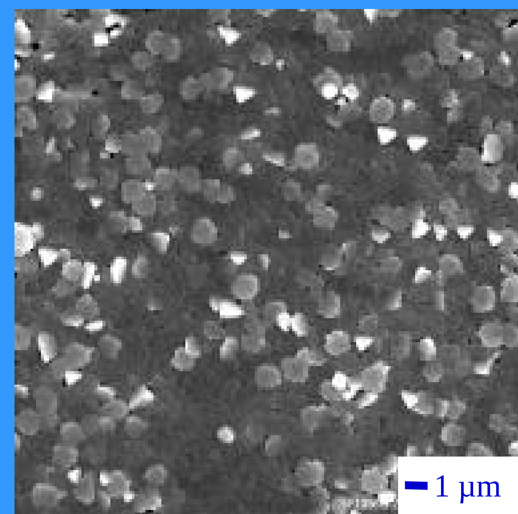
The multilayer approach produces a relatively smooth and dense coating and dramatically increases thick film J_c

3.0 µm YBCO standard process



J_c = 0.6 MA/cm^2
I_c = 180 A/cm-width

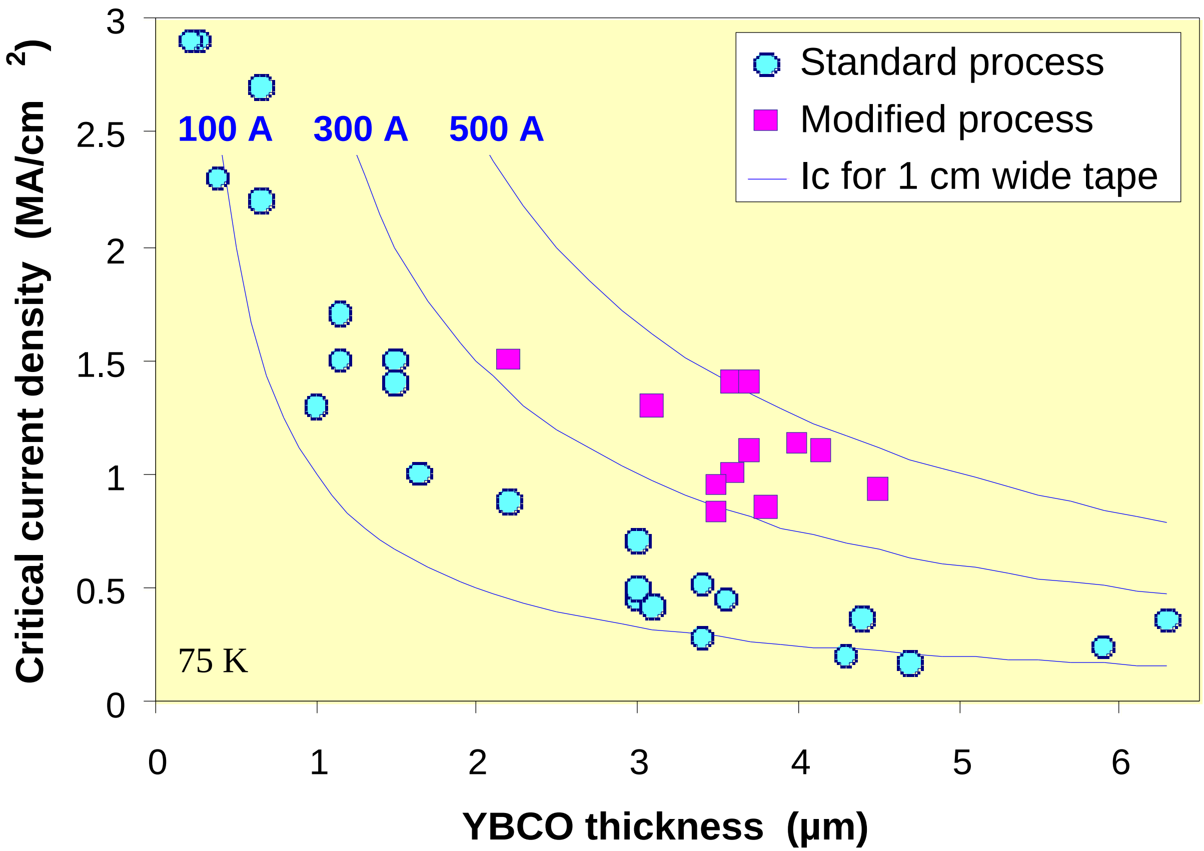
3.7 µm Y/Sm multilayer



J_c = 1.1 MA/cm^2
I_c = 405 A/cm-width

Y/Sm-123 multilayers have allowed us to overcome the 200 A "barrier", as described at the Peer Review last year

Substrate: Inconel 625 with IBAD YSZ – Bridge dimensions: ~200 μm x 5 mm



A source of IBAD YSZ was needed in order to continue multilayer research

Problem

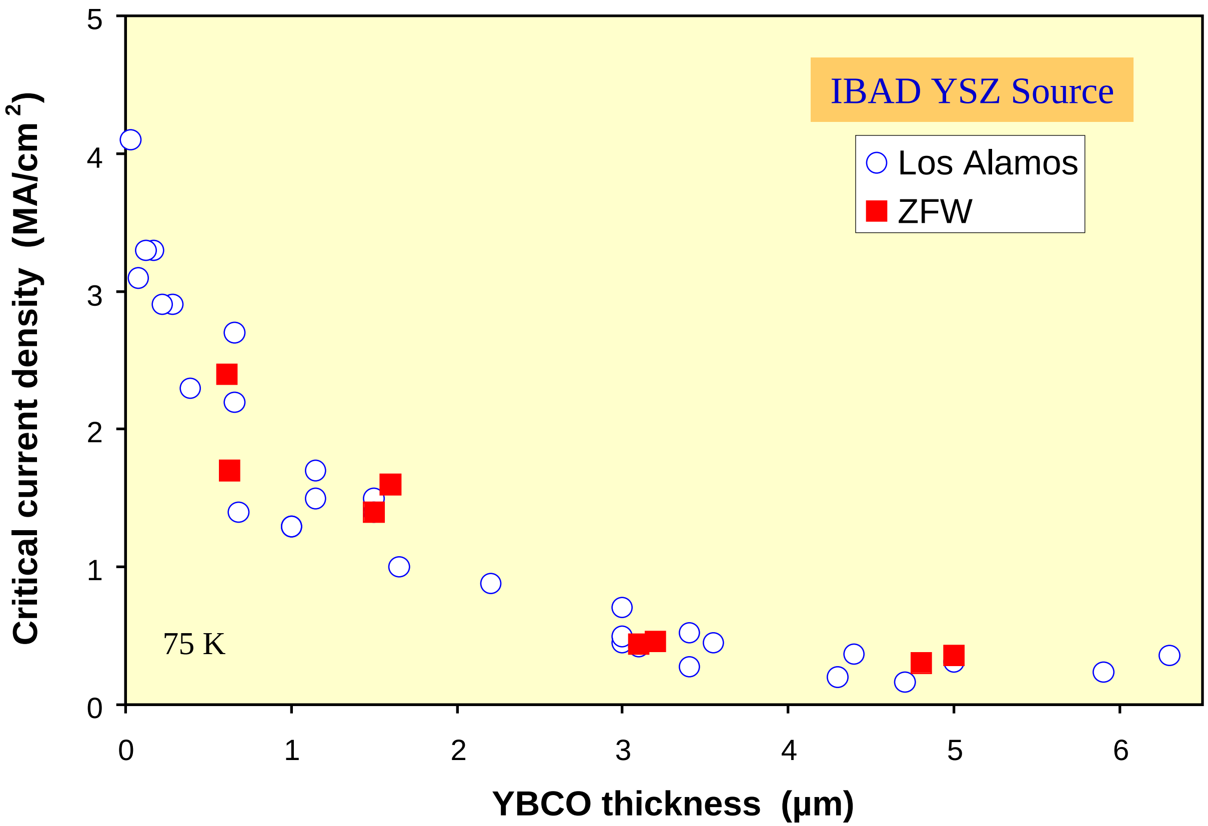
Los Alamos is now focusing exclusively on IBAD MgO template technology, but the YBCO performance achieved with IBAD YSZ has not yet been duplicated with MgO.

Solution

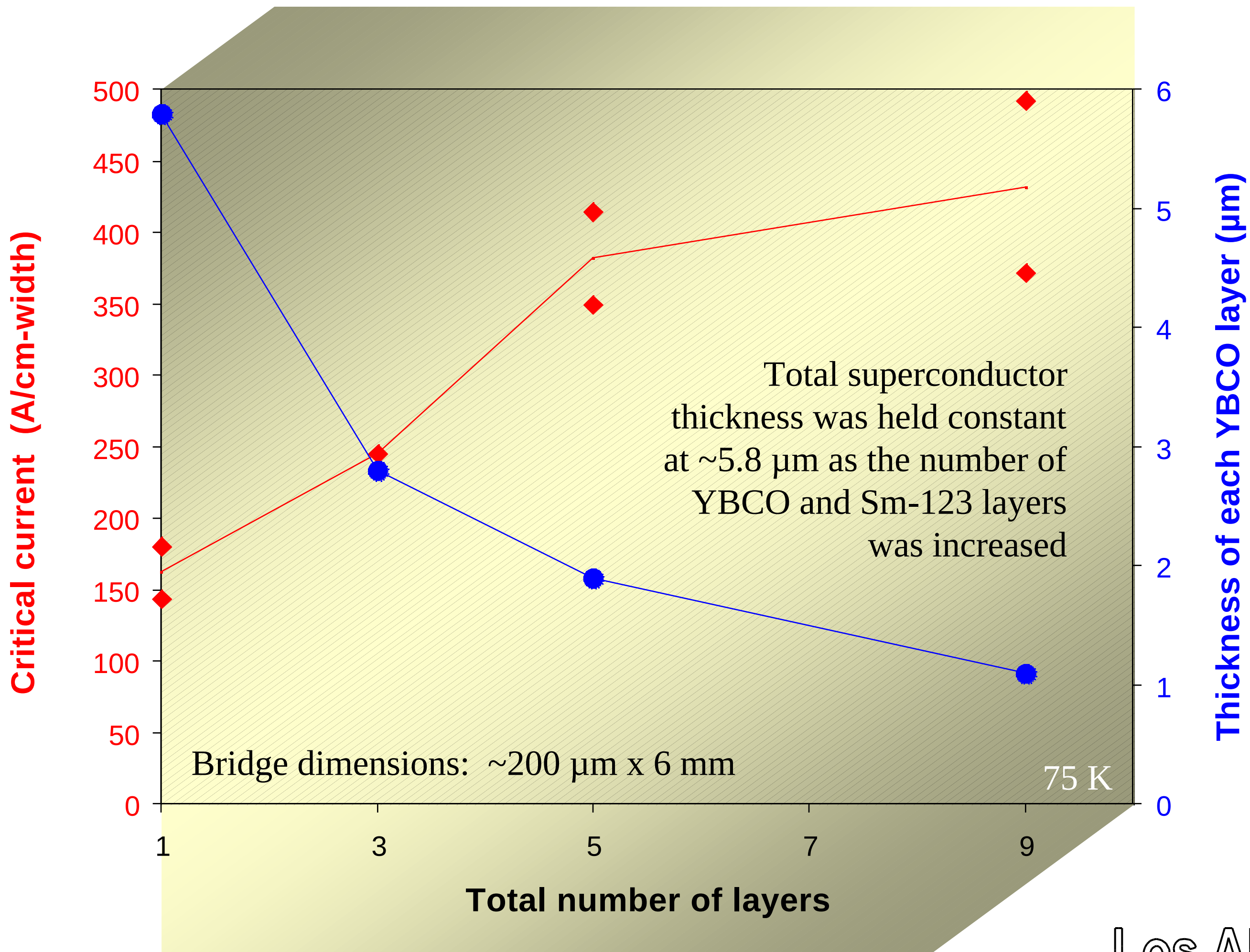
Obtain high-quality IBAD YSZ. Source: Center for Applied Materials Development (ZFW), in Göettingen, Germany.

Performance results for YBCO are the same for both IBAD YSZ sources

Standard YBCO single layers with Y_2O_3 or CeO_2 buffer layers and Inconel 625 substrates



At a given total thickness, multilayer I_c increases with the number of layers deposited



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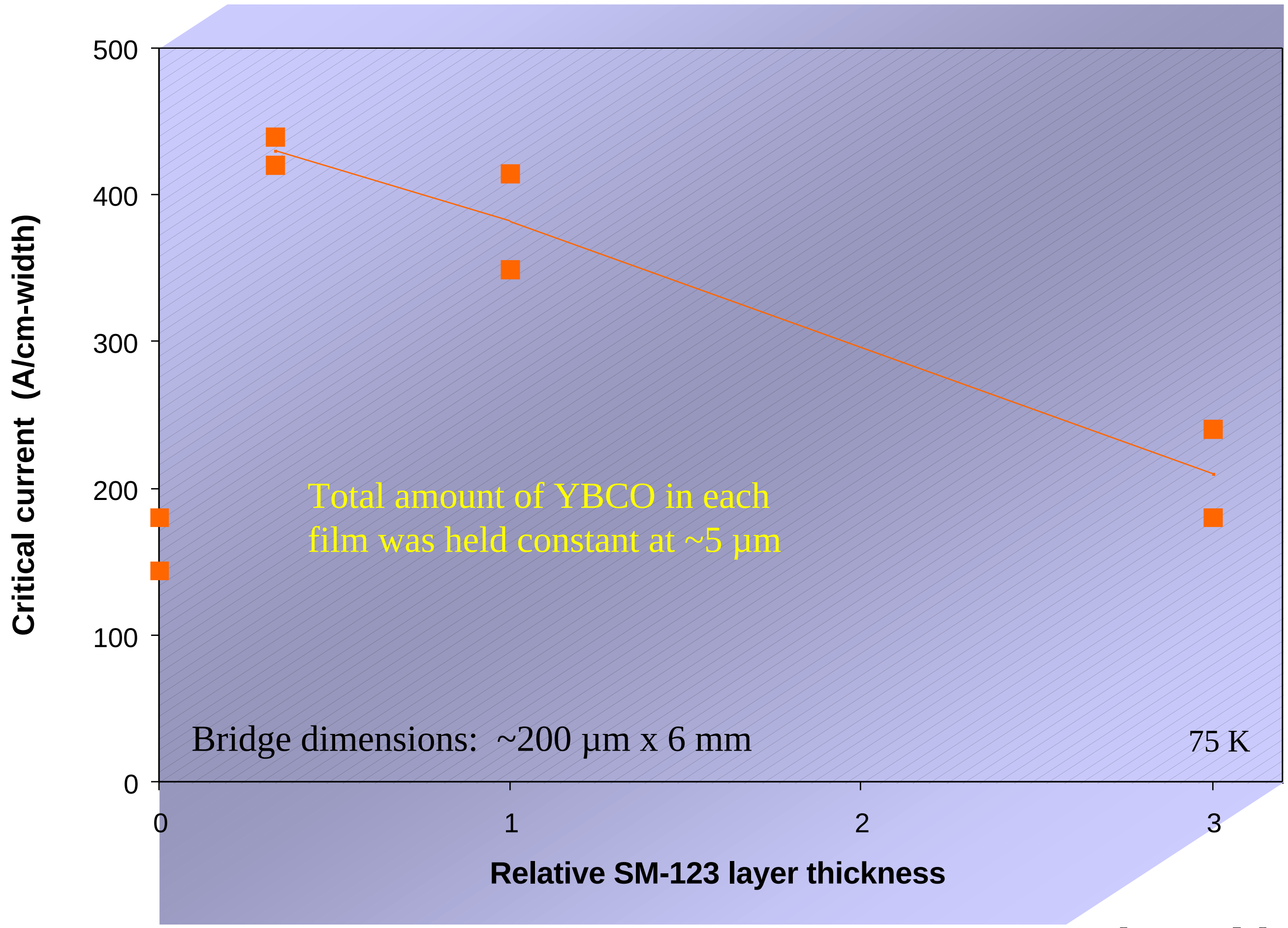
Critical current also depends strongly on the Sm-123 interlayer thickness



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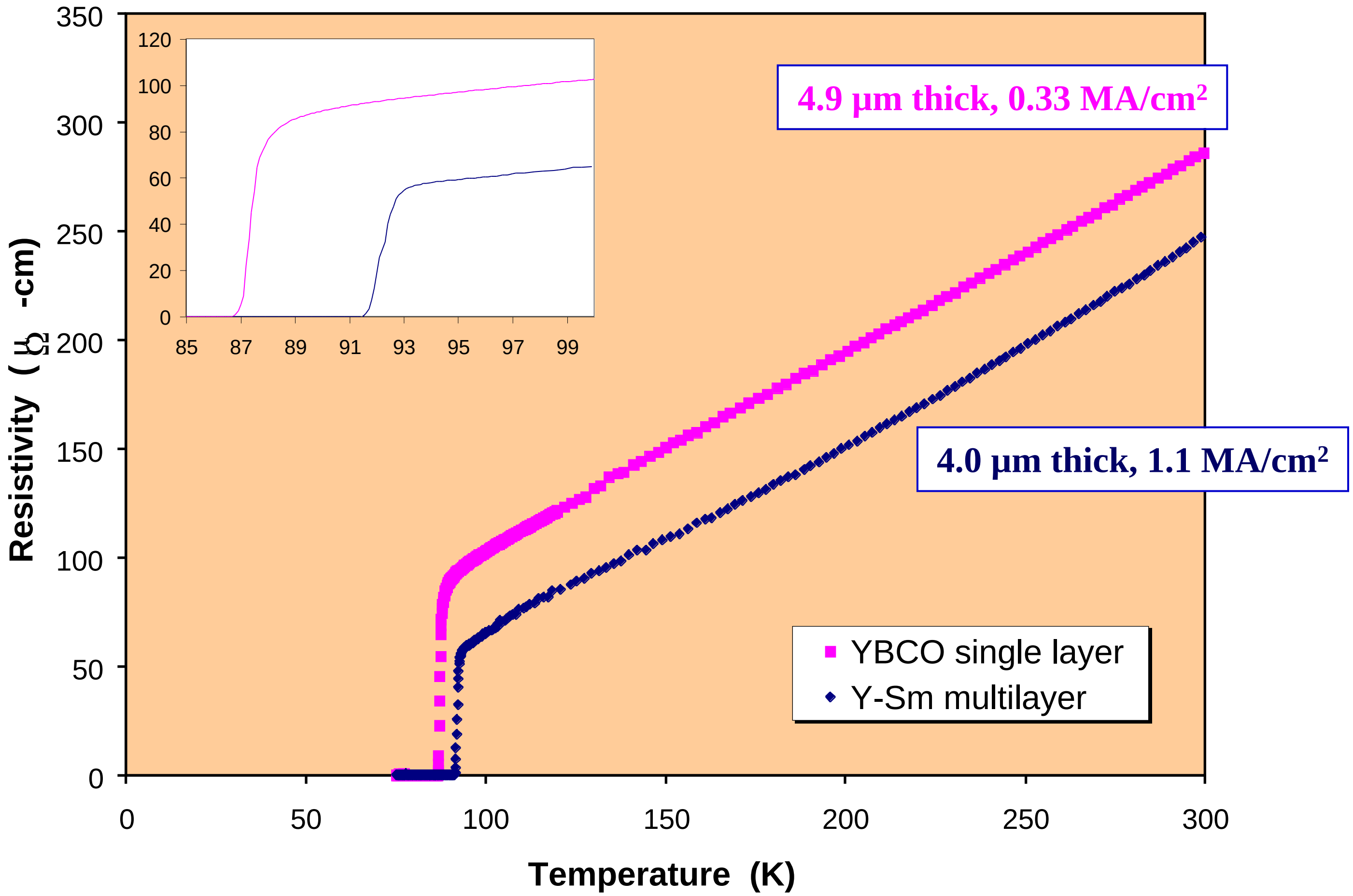
The typical thick multilayer has lower resistivity and higher T_c than a comparable single layer YBCO film



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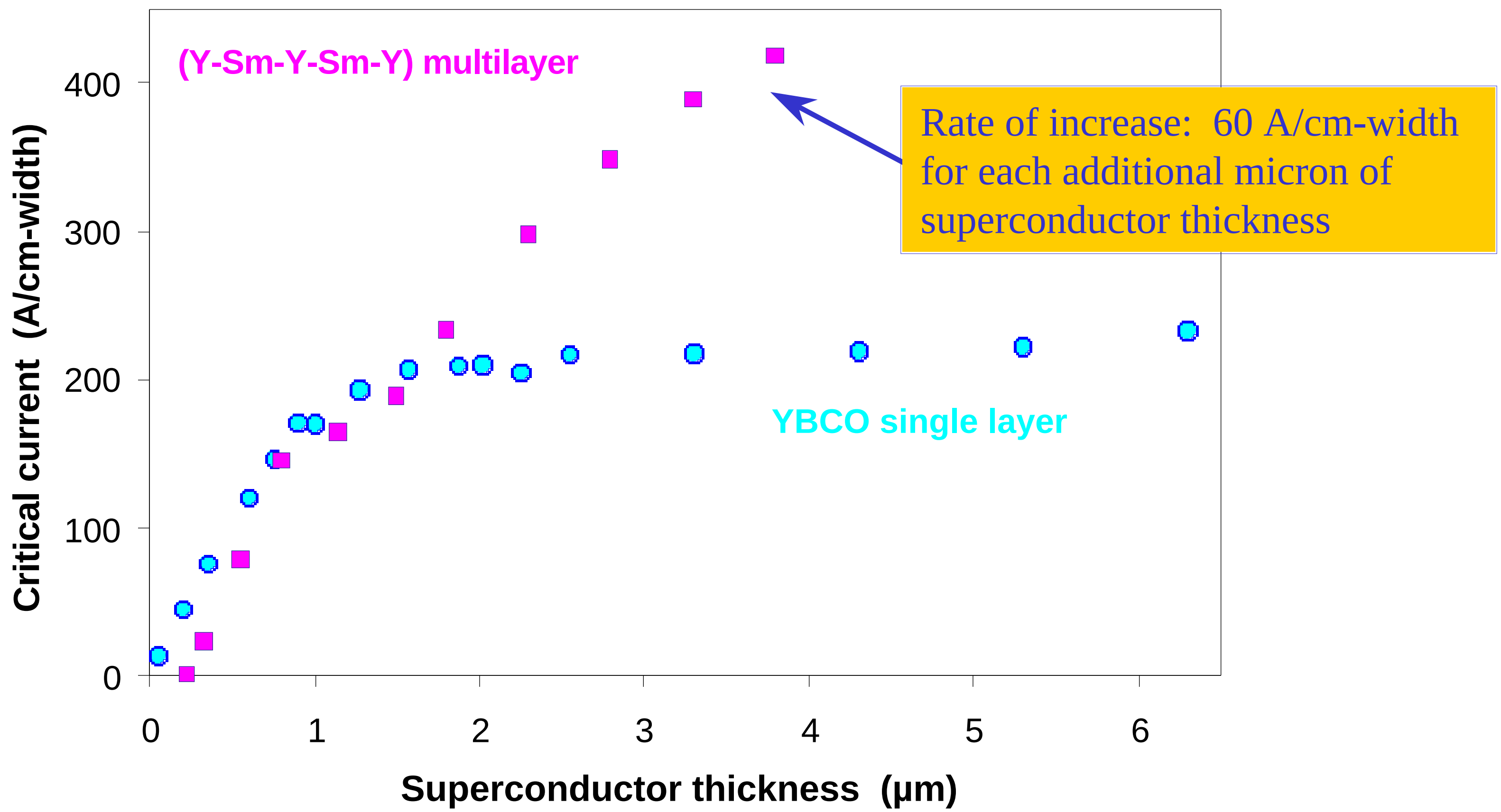
Multilayer performance increase is due mainly to improvement of connectivity above a thickness of ~1.5 µm



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The multilayer process was transferred to our PLD tape coating chamber

- ★ A conservative 3-layer design (Y-Sm-Y) was used.
- ★ One-meter-long IBAD YSZ tapes from Germany were first coated with CeO_2 by PLD.
- ★ Total superconductor thickness was ~ 2 µm.
- ★ I_c of the first tape was 142 A.

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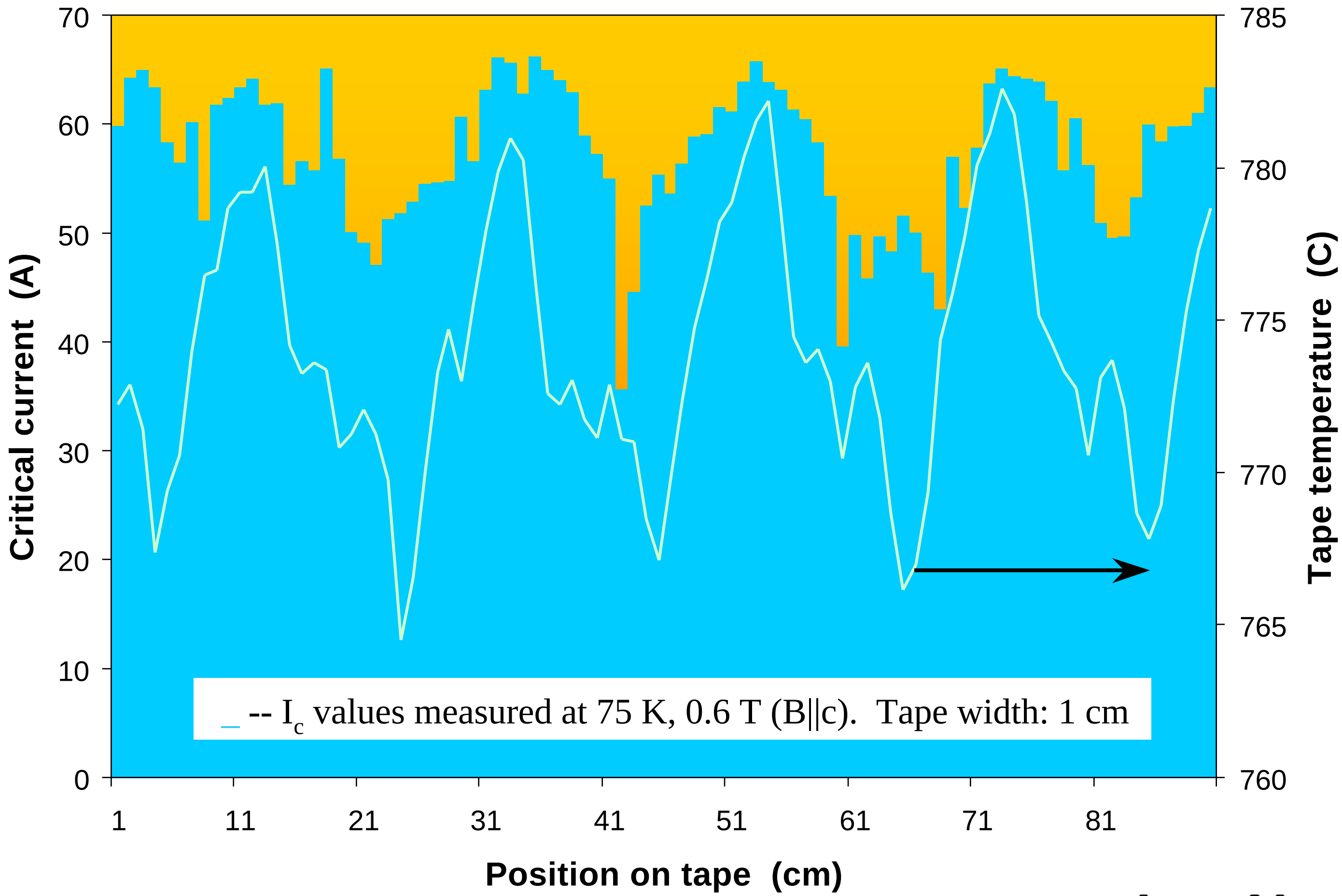
In a second tape, periodic variations in I_c were observed that indicated a problem with deposition temperature

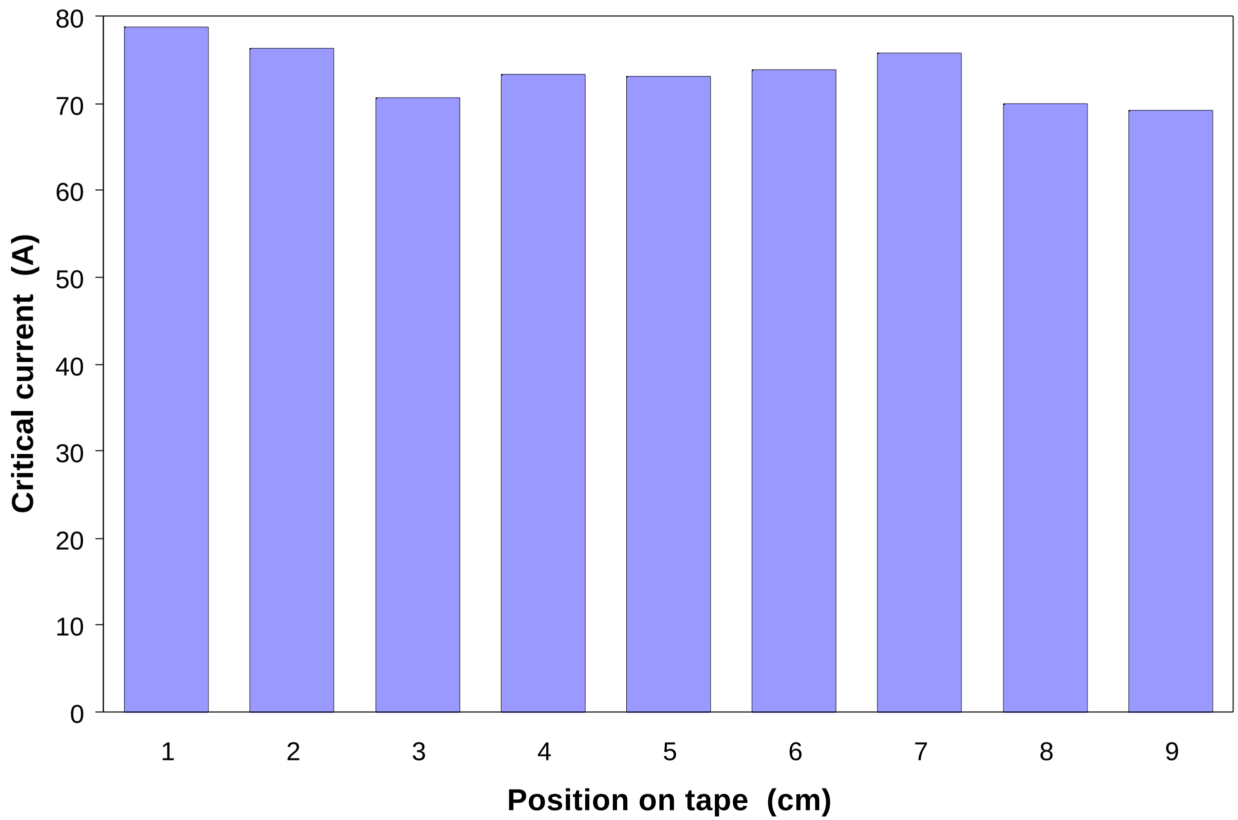


Even with the temperature problem, end-to-end I_c of the tape was at a record level

- In self-field, full-length I_c is 189 A (75 K).
- At 0.6 T, lowest valley (determines full-length I_c) is 35 A.
- Peaks in the I_c distribution are at 65 A.
- Self-field I_c of the peak regions should be ~ 350 A.
- Deposition temperature was too low – easily fixed.

Temperature was increased and a 20 cm segment was coated, resulting in 9 cm of measurable length

I_c along the length of a cm-wide tape measured at 75 K, 0.6 T (B||c)



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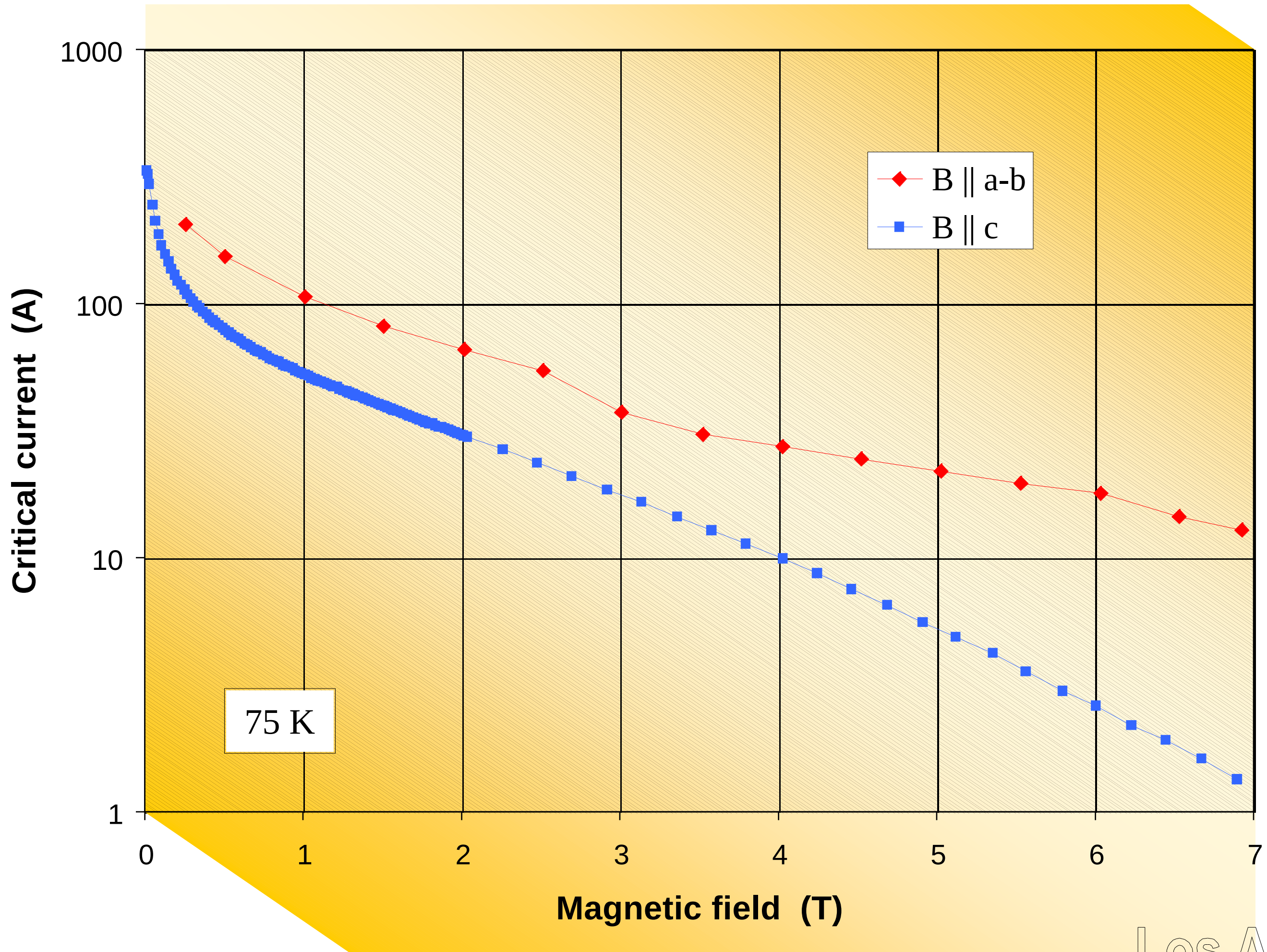
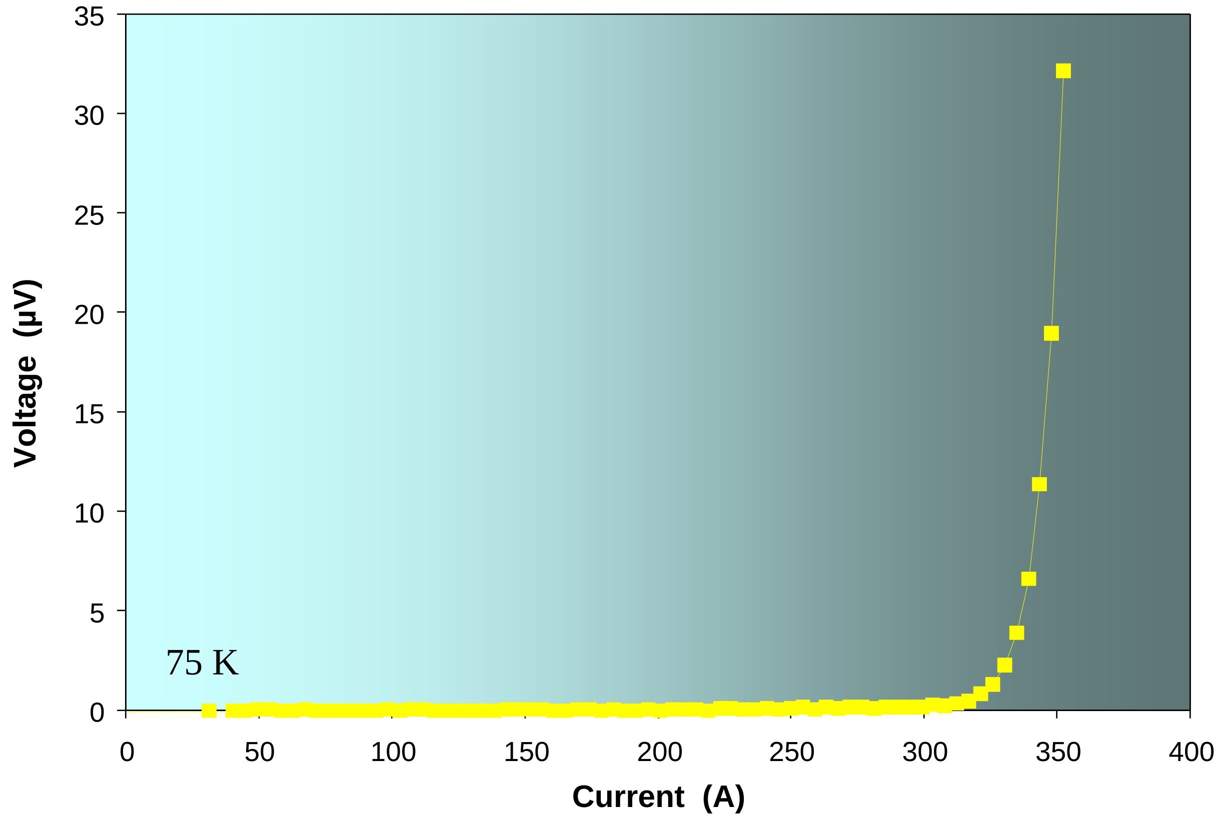
We next measured the central 5 cm of the tape in field



The highest I_c measured as the external field approached zero was ~ 335 A



Finally, a cm-long piece of the tape was patterned into bridges to yield more information

- Superconductor thickness: 1.9 μm
- Estimated thickness of each YBCO layer: 0.9 μm
- T_c (inductive): 92.8 K
- J_c of the bridges (~200 μm x 5 mm): 2.05 & 2.15 MA/cm^2
- Extrapolated I_c: 400 A/cm-width

Conclusions

- We have found that Y/Sm-123 multilayers can be improved by reducing the Sm layer thickness and by increasing the number of layers.
- Using a conservative multilayer design (only 3 layers), we have produced a short, continuously processed tape with $I_c > 335$ A.
- The same multilayer design was extended to two one-meter lengths with resulting I_cs of 142 A and 189 A.
- The multilayer approach is a viable method for greatly increasing coated conductor performance.